(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 864 882 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.09.1998 Bulletin 1998/38

(51) Int. Cl.[6]: G01V 1/28

(21) Application number: 98200712.2

(22) Date of filing: 06.03.1998

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 10.03.1997 US 814276

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(54) Method for estimating or simulating parameters of a stratum structure

(57) The present invention provides for a method for estimating or simulating one or more parameters of a stratum structure, comprising the steps of:

- determining a first model of the stratum structure;
- determining one or more variograms of one or more parameters in one or more of the strata;
- measuring the value of a parameter in a number of points;
- estimating on the basis of a variogram a probability density function (PDF) of the parameter at locations in the strata close to or at some distance from the locations where the parameter has been measured; and
- determining by using seismic data an acceptable value of the parameter at the location where the probability density function of the parameter has been determined using a variogram.

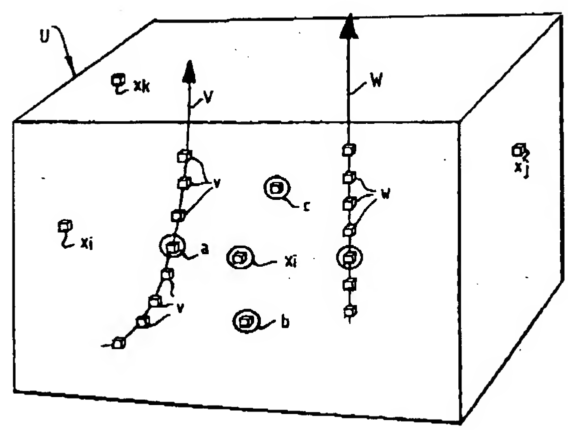

FIG.1

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Description

Particularly for locating oil and/or gas in the earth's crust it is important to obtain the best possible estimation of a stratum structure, for instance using seismic inversion techniques, whereafter it can be assessed whether (test) drilling for oil and/or gas can be carried out at a particular location on the earth's surface. Also after carrying out one or more test drillings, the costs of which are very high, examination of the stratum structure continues, likewise using the measurement data obtained from the wells.

In the article by André Haas et al: "Geostatical Inversion - A Sequential Method of Stochastic Reservoir Modelling constrained by Seismic Data", First Break vol 12, No 11, November 1994/561, geostatical simulations are used at an earlier stage of the inversion process. This know computer scheme is however quite complicated, e.g. because it is necessary to calculate synthetic traces.

The present invention provides a method for estimating or simulating one or more parameters of a stratum structure, comprising the steps of:

- determining a first model of the stratum structure;
- determining one or more variograms of one or more parameters in one or more of the strata;
- measuring the value of a parameter in a number of points;
- estimating on the basis of a variogram a probability density function (PDF) of the parameter at locations in the strata close to or at some distance from the locations where the parameter has been measured; and
- determining by using seismic data an acceptable value of the parameter at the location where the probability density function of the parameter has been determined using a variogram.

According to the present invention geostatistical techniques are combined with deterministic techniques which make use of seismic data, whereby the uncertainty in the solution of the model can be considerably reduced.

The stratum structure is usually built up of sandstones, shale and/or limestone-type rocks. Significant parameters are for instance the specific density, the porosity, the permeability and the like of such strata. The first model of the stratum structure on which iterative (better) estimations are performed is determined for instance using seismic, geological and/or well data. The variogram of the parameter can be determined on the basis of the experience of a geologist, measurements on a well and/or from samples obtained from a well.

Further advantages, features and details of the present invention will be elucidated with reference to the annexed drawings, in which:

fig. 1 shows a diagram elucidating a preferred embodiment of the method according to the present invention;

fig. 2 shows a graph of a variogram for use in the preferred embodiment according to the present invention;

fig. 3 shows a graph of an example of a probability density function for use in the method according to the present invention;

fig. 4 shows a flow diagram explaining the preferred embodiment of the method according to the present invention;

fig. 5 shows a flow diagram explaining a further preferred embodiment of the method of the present invention; and

fig. 6 shows a flow diagram of a preferred embodiment wherein the methods according to fig. 4 and 5 are combined.

In a schematically designated area U (fig. 1) of a stratum structure, in which for instance two boreholes V and W are arranged, the parameter, for instance the porosity, must be determined of a large number of points - x, x_i, x_j and x_k are shown - while the property of the structure at locations v and w at the respective boreholes V and W are known with a certain accuracy, for instance because measurements are carried out with probes along the boreholes and/or samples are taken.

In a preferred embodiment of the present invention a structural (geometric) model is first created on the basis of seismic measurement data at the earth's surface. Reflection surfaces which are considered important are formed to a structure of closed strata, for instance by the computer program EARTH MODEL commercially available from applicant, wherein a geologist can make determined choices. The program EARTH MODEL defines the geological layers as well as the micro-structure in such a layer. It will be apparent that according to the present invention other methods may also be envisaged to obtain an initial simulated stratum structure.

Variograms (fig. 2) (and/or histograms) are subsequently defined for a particular parameter, such as the porosity in determined layers. In a variogram such as in fig. 2 the correlation or variance is determined between two values of a parameter given at different spatial locations, i.e. as a function of the distance between two locations. A variogram between two different parameters, for instance between porosity and permeability, is referred to as a cross-variogram. At a determined distance the variogram becomes horizontal, above which distance the spatial correlation amounts to zero. The variance therefore has a constant value at a distance beyond this distance. In the case a variogram is anisotropic in a particular stratum, this distance has a different value in each case for different directions, thus forming as it were an ellipsoid.

In order to determine the parameter in the point x_1,

which can be chosen randomly (or according to more advanced probability techniques which are not discussed here), a number of points, for instance a, b, c and d, where the value of this parameter is known (or is already present in the model and has been determined previously in the same manner) are chosen in the vicinity of this point x_1. Via the probability density function found on the basis of the variograms a value for the parameter is chosen randomly and stored for the point x_1. The thus simulated point is added to the known value and the procedure is repeated until all points x_i in the space U have been simulated and a value assigned thereto.

The above stated preferred method differs from the so-called Kriging method (or in the case of cross-variograms co-Kriging) in that therein the most probable value is determined from the variograms (see C.V. Deutsch and A.G. Journel (1992), GSLIB: geostatistical software library and user's guide, Oxford University Press, New York).

In the stochastic techniques an estimation of the uncertainty in the estimated model reservoir is available, wherein the reservoir models fit available geostatistical information, such as variograms and histograms (i.e. wherein the data has a Gaussian distribution).

According to the present invention the models, such as obtained with the above mentioned stochastic simulation, are subsequently checked against seismic data. Instead of the parameters being estimated exclusively according to stochastic simulations, after obtaining a first stochastic model it is determined using seismic data whether or not a new iteration point fits better in the model than the previously found point.

This takes place by convoluting synthetic seismic data with a "wavelet" and comparing the outcome with the measured seismic data. If the value of the iteration point is no better than the previous point, this iteration step is rejected and the old value of the point is stored in the model.

Due to the combination of stochastic simulation and application of seismic data, wherein iterations can continue until a satisfactory correlation between the reservoir model and the seismic data is obtained, there results an estimation or model for the values of the parameters in the various points which suffice optimally on the basis of the geostatistical data.

In the flow diagram according to fig. 4 various aspects are elucidated further: firstly (10) a point or node x_i is selected randomly. The conditional local probability density function of the reservoir property is then estimated (11); the realization is drawn therefrom (12), which procedure is repeated until all grid nodes are dealt with.

In fig. 5 a similar method is shown wherein firstly a grid node (20) is selected at random, the conditional local probability density function is then determined subject to a particular lithology (indicator) (21), whereafter the realization lithology from the local probability density function is drawn (22) until the random path (23) is complete.

Fig. 6 shows the preferred embodiment, wherein the procedures of fig. 4 and 5 are combined and wherein the convergence step for the seismic data is shown in block 31.

First experiments with the method according to the present invention have shown that the cumulative probability in the 10/90% probability interval is considerably smaller in the method according to the present invention than using the known geostatistical methods.

The present invention is not limited to the above described preferred embodiment; the requested rights are determined by the following claims, within the scope of which many modifications can be envisaged.

Claims

1. A method for estimating or simulating one or more parameters of a stratum structure, comprising the following steps:

   - determining a first model of the stratum structure;
   - determining one or more variograms of one or more parameters in one or more of the strata;
   - measuring the value of a parameter in a number of points;
   - estimating on the basis of a variogram a probability density function (PDF) of the parameter at locations in the strata close to or at some distance from the locations where the parameter has been measured; and
   - determining by using seismic data an acceptable value of the parameter at the location where the probability density function of the parameter has been determined using a variogram.

2. A method for estimating or simulating one or more parameters of a stratum structure, comprising the steps of:

   a) obtaining seismic data of the stratum structure;
   b) determining from the obtained seismic data a first model of the stratum structure;
   c) determining from the first model one or more variograms of one or more parameters in one or more strata of the stratum structure;
   d) measuring a value for the one or more parameters at a plurality of points in the stratum structure;
   e) estimating on the basis of the one or more variograms a probability density function (PDF) of the one or more parameters at other points in the strata one of adjacent and distant from the points where the one or more parameters were measured; and

f) determining by using the probability density function a value for each of the one or more parameters in the strata at the points where the probability density function of the parameter were determined;

g) combining the values determined in step f) with the corresponding one or more parameters determined from the first model;

h) obtaining from one or more parameters determined in step g) acceptable values for the one or more parameters in the stratum structure; and

i) generating from the acceptable values for the one or more parameters a second model of the stratum structure.

3. A method as claimed in claim 1 or 2, wherein for each location two parameters are simulated using a cross-variogram.

4. A method as claimed in claim 1, 2 or 3, wherein the probability density function is selected on the basis of an indicator for the type of lithology to be expected.

5. A method as claimed in claims 1-4, wherein the one or more variograms are determined on the basis of available data of a stratum obtained from samples thereof.

6. A method as claimed in claims 1-5, wherein one or more parameters are measured in a borehole.

7. A method as claimed in claims 1-6, wherein the steps are repeated until an estimation is obtained of desired accuracy.

8. A method as claimed in claims 1-7, wherein the one or more variograms are determined on the basis of available data of the stratum obtained from samples thereof.

9. The method as claimed in claim 1, wherein step (h) comprises the steps of:

convoluting the one or more parameters determined in step (g) with a wavelet to obtain convoluted one or more parameters;

comparing the convoluted one or more parameters with corresponding one or more parameters determined from the first model; and

retaining the obtaining convoluted one or more parameters as the acceptable values if the obtained convoluted one or more parameters improve a cumulative probability of the probability density function over the one or more parameters from the first model.

10. The method as claimed in claim 9, further including repeating steps (g) - (i) until a desired correlation is obtained between the one or more parameters in the first model and the one or more parameters in the second model.

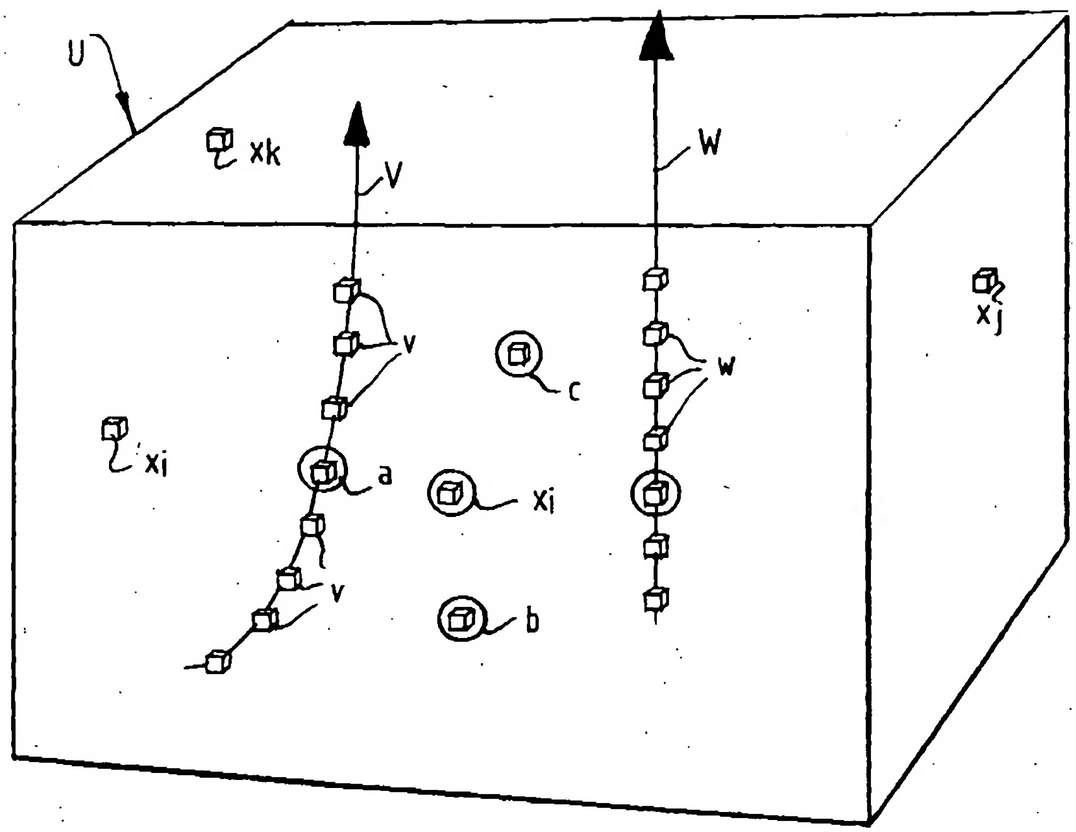
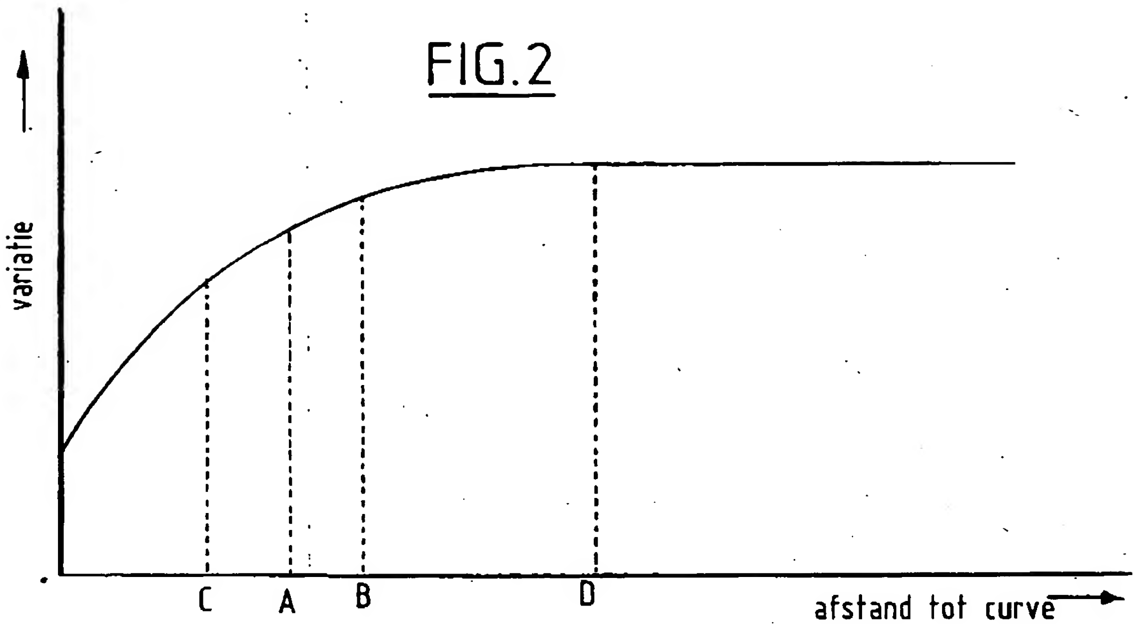


FIG.1

FIG.2


variatie
C
A
B
D
afstand tot curve

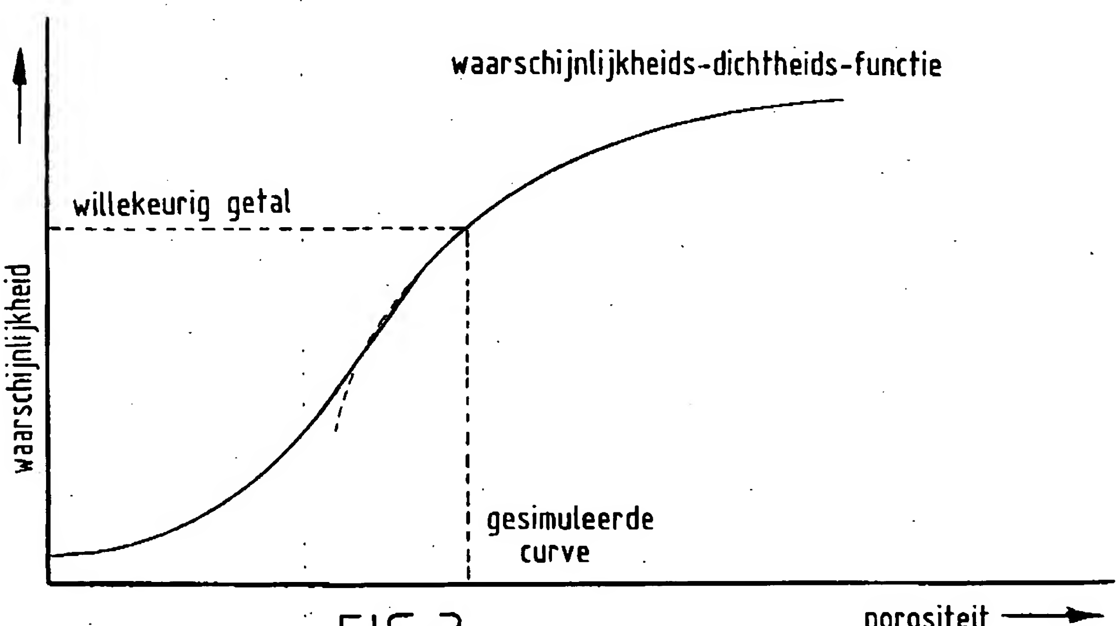

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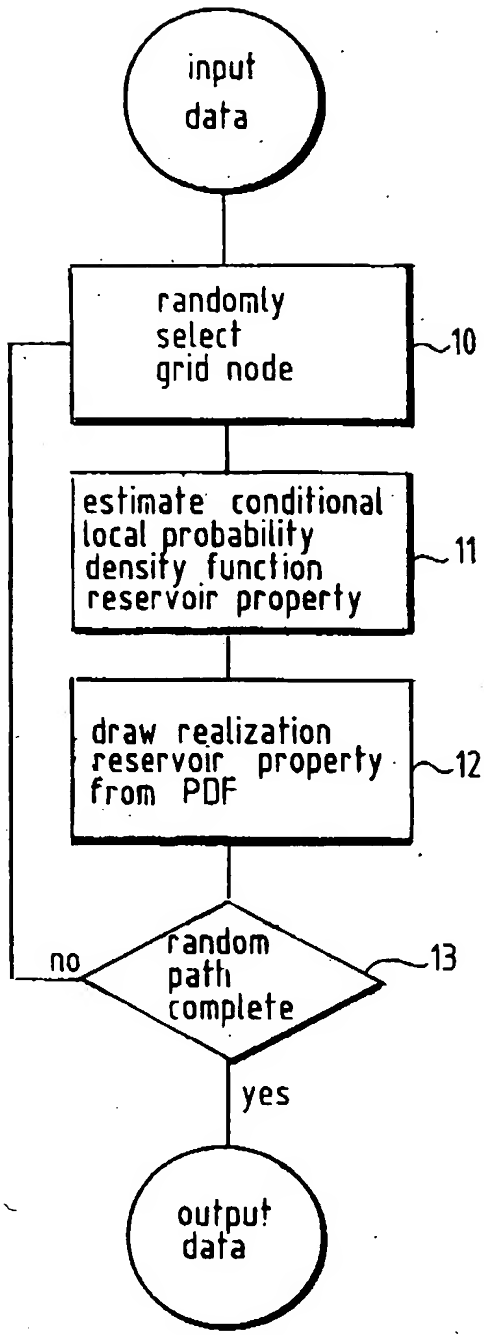
FIG.3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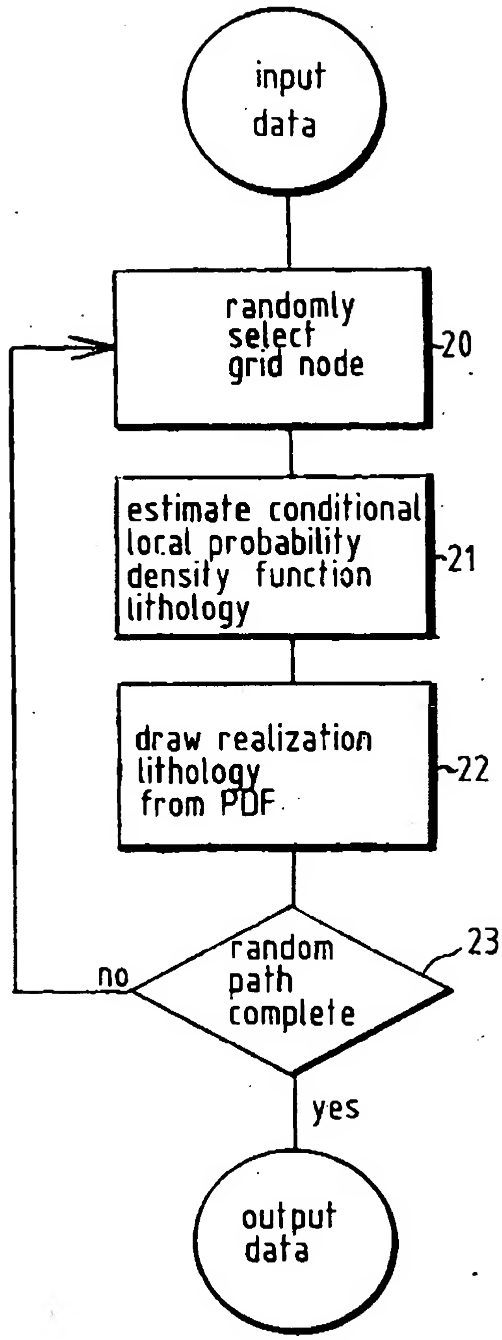
estimate conditional local probability density function reservoir property
11
draw realization reservoir property from PDF
12
random path complete
13
no
yes
output data

FIG. 4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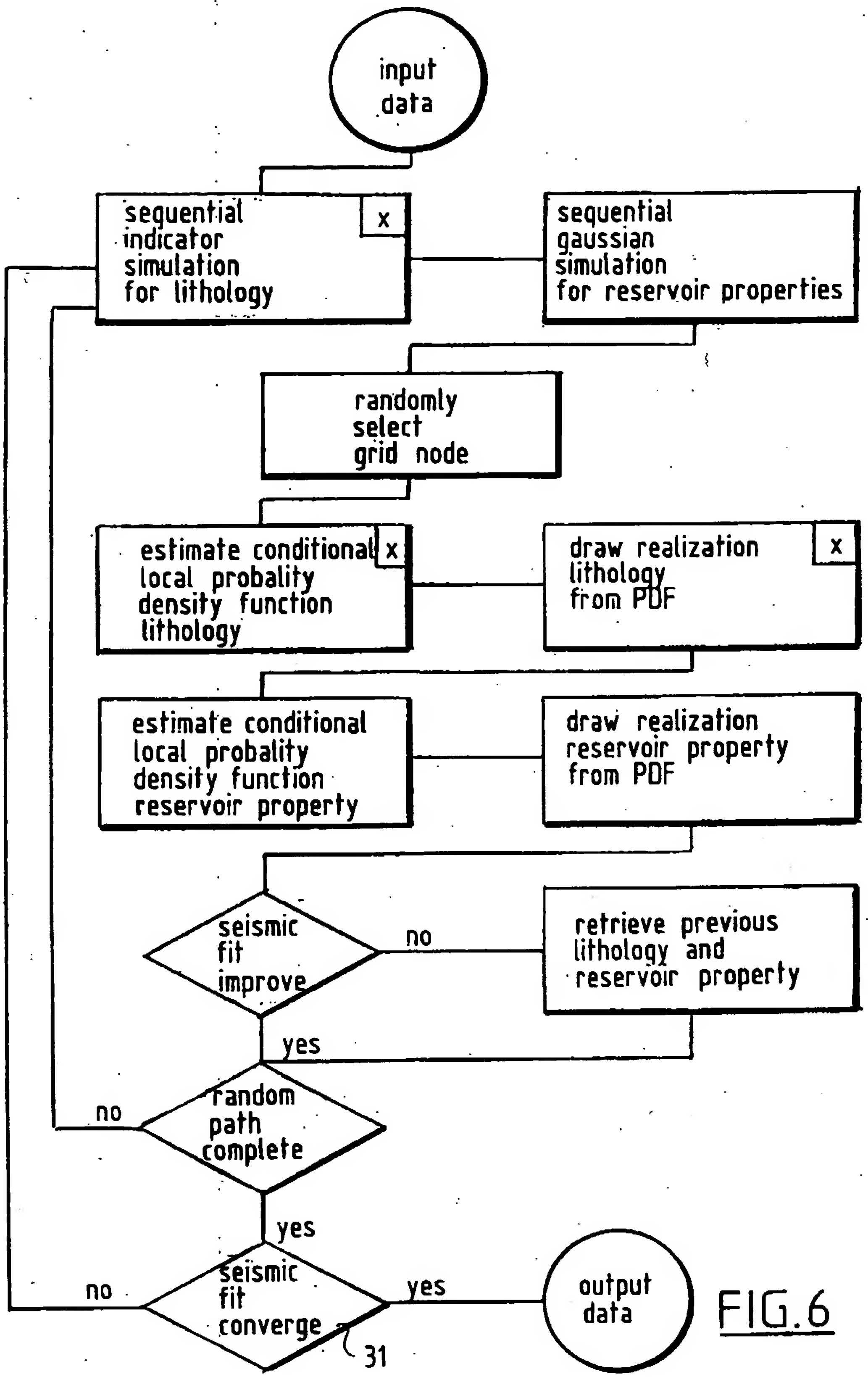
estimate conditional local probability density function lithology
21
draw realization lithology from PDF
22
random path complete
23
no
yes
output data

FIG. 5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sequential gaussian simulation for reservoir properties
randomly select grid node
estimate conditional local probality density function lithology
x
draw realization lithology from PDF
x
estimate conditional local probality density function reservoir property
draw realization reservoir property from PDF
seismic fit improve
no
retrieve previous lithology and reservoir property
yes
random path complete
no
yes
seismic fit converge
no
yes
output data
31

FIG.6